Original Article

Single dose epidural methylprednisolone as a treatment and predictor of outcome following subsequent decompressive surgery in degenerative lumbosacral stenosis with foraminal stenosis

S.A. Gomes [a,] *, M. Lowrie [a], M. Targett [b]

[a]*Dovecote Veterinary Hospital, 5 Delven Lane, Castle Donington, Derby DE74 2LJ, UK*
[b]*School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington, Leicestershire, LE12 5RD, UK*

* Corresponding author. Tel.: +44 1332 810395.
E-mail address: sergio.gomes@dovecoteveterinaryhospital.co.uk (S.A. Gomes).

Abstract

Alternative treatments to surgery in canine degenerative lumbosacral stenosis (DLSS) remain limited and reliable predictors of outcome are lacking. The aims of this clinical trial were threefold: to assess the usefulness of single epidural steroid injection (ESI) in DLSS, to compare the outcomes of ESI and decompressive surgery, and evaluate ESI as a predictor of outcome following decompressive surgery.

Dogs diagnosed with DLSS were prospectively recruited and administered an ESI. If clinical signs persisted or relapsed, decompressive surgery was recommended. Follow-up was obtained. Thirty-two dogs underwent ESI with 17 having subsequent surgery. Improvement after ESI was seen in 27/32 dogs (84.4%), with 17/22 (77.2%) relapsing within six months (15/17 relapsing within two months). Five dogs failed to respond to ESI and another five (15.6%) presented a persistent post-ESI favourable response (mean follow-up time, 9.4 months). Post-surgical improvement occurred in all dogs. Outcome appeared more favourable following surgical decompression, with a trend towards reduced pain, increased mobility, and greater quality of life score.

This study was unable to demonstrate that ESI could predict surgical outcome. ESI was confirmed as an effective treatment in most but not all cases, leading to transient alleviation of clinical signs for longer than previously reported. ESI provided a complete and apparently long-term sustained resolution of clinical signs in a subset of dogs. Despite this, there was indication that surgical decompression can lead to a more favourable outcome. Epidural steroid injection has a role in the management of DLSS dogs, particularly when surgery is not an option.

Keywords: Cauda equina; Dog; Foraminotomy; Spinal surgery; Veterinary

Introduction

Degenerative Lumbosacral Stenosis (DLSS) is an acquired multifactorial condition, involving alterations of the tissues surrounding the cauda equina and nerve roots, where progressive stenosis of the vertebral canal and/or the intervertebral foramina gives rise to neurological dysfunction and pain in dogs (De Risio et al., 2001; Gödde and Steffen, 2007; Jeffery et al., 2014; Gomes et al., 2018). Several treatment strategies have been described in addressing DLSS with variable success. Reports describing conservative management alone revealed improvement in the clinical signs in about 50% of dogs, being based on the adoption of non-standardised protocols, with different medications and restricted exercise (Denny et al., 1982; Ness, 1994; De Decker et al., 2014). Surgical management of DLSS has been more extensively reported with clinical improvement identified in 67% to 97% of cases (Danielsson and Sjöström, 1999; Janssens et al., 2000; Jones et al. 2000; De Risio et al., 2001; Linn et al., 2003; Gödde and Steffen, 2007; Suwankong et al., 2008; Hankin et al., 2012; Smolders et al., 2012; Golini et al., 2014; Gomes et al., 2018).

An alternative method has been described in a single retrospective study, through the infiltration of methylprednisolone acetate in the epidural space over the L7-S1 intervertebral disc in a population of 38 dogs (Janssens et al., 2009). Although this has not yet been established in veterinary medicine, the terminology “epidural steroid injection” (ESI) is used in human medicine to describe this procedure (Buttermann, 2004; McLain et al., 2005; Wilkinson and Cohen, 2013) and seems an appropriate term for veterinary patients. We define this term as the translaminar instillation of methylprednisolone acetate into the epidural region over the L7-S1 intervertebral disc as described by Janssen and others (Janssen et al., 2009).

In that same report (Janssen et al., 2009), all dogs were reported to improve

following the first ESI with 18.4% receiving a single-instillation, and long-term clinical improvement reported in 79% of dogs following more than one ESI. Specific details on outcome of the subpopulation receiving a single-instillation are not described or are difficult to infer, and it is questionable if a single ESI can be applied successfully as treatment in DLSS affected dogs. The study also demonstrated that ESI had a temporary effect, requiring several repeated procedures to achieve a more prolonged effect (Janssens et al., 2009). The same study based DLSS diagnosis on epidurography or discography with no advanced imaging being performed. No further articles have investigated ESI efficacy in canine DLSS.

Epidural steroid injection is generally considered a safe procedure in dogs (Janssens et al., 2009; Liotta et al., 2016; Salmelin et al., 2019). The theoretical advantages of ESI over oral medication include a more targeted therapy, being applied in the immediate vicinity of the affected nerve roots, potentially leading to less systemic effects and higher local dosages (McLain et al., 2005). These advantages, allied with a rapid response to treatment, gives ESI the potential of being used as a single treatment, a diagnostic test or even as predictor of subsequent outcome following surgical management of DLSS. Several prognostic factors for post-surgical failure in DLSS have been reported including the presence of faecal or urinary incontinence, urinary incontinence of more than one month in duration (De Risio et al., 2001; Linn et al., 2003), increased age of onset of clinical signs, radiographic presence of foraminal narrowing, presence of paresis, proprioceptive deficits, pelvic limb muscle atrophy and the identification of hypertrophic articular facets and the interarcuate ligament intraoperatively (Linn et al., 2003). However, no diagnostic test has been identified predicting post-surgical outcome in DLSS. Epidural steroid injection appears to be a

good candidate for this purpose due to its rapid relief of clinical signs when effective, and the ability to perform the procedure at the time of advanced imaging diagnosis.

The aims of this clinical trial were threefold; to assess the usefulness of single instillation ESI in the treatment of DLSS, to compare the outcomes of ESI and decompressive surgery, and to evaluate the clinical response of ESI as a predictor of outcome for subsequent decompressive surgery. We hypothesise that a successful but transient response to ESI could be an indicator of a successful outcome of subsequent surgical decompression.

Material and Methods

Study design

This prospective study was based on previously validated treatment options for DLSS affected dogs (Gödde and Steffen, 2007; Janssens et al., 2009; Gomes et al., 2018). Ethical approval for the study was granted by The School of Veterinary Medicine and Science at the University of Nottingham (Approval number: 2711 190326; Approval date: 10 May 2019). Written informed consent was obtained from owners of all dogs prior to enrollment.

Dogs presented to the neurology service at a single referral hospital between February 2017 and May 2019, with clinical signs compatible with DLSS were consecutively prospectively recruited.

Inclusion criteria were (1) clinical confirmation of DLSS through compatible clinical signs, (2) magnetic resonance imaging (MRI) evidence of intervertebral foraminal stenosis with identification of L7 nerve root enlargement and/or lumbosacral vertebral canal stenosis (Gödde and Steffen, 2007; Gomes et al., 2018). Evidence of foraminal stenosis was based on one or more of the criteria: (1) complete loss of fat

signal or only a minimal rim of fat signal left in the foraminal zone in parasagittal or transverse T2W images; (2) presence of a compressive asymmetric intervertebral disc protrusion on transverse T2W images at the level of the intervertebral foramina; (3) the presence of an ipsilateral hyperintense L7 nerve root on transverse T2W images and dorsal STIR. Evidence of vertebral canal stenosis was based on the presence of over 25 per cent of lumbosacral vertebral canal attenuation on midsagittal images, including compression secondary to L7-S1 intervertebral disc protrusion (Gödde and Steffen, 2007; Gomes et al., 2018).

Dogs presenting with concomitant relevant orthopaedic, neoplastic, inflammatory, developmental conditions or evidence of L7-S1 intervertebral disc extrusion were excluded. Concomitant orthopaedic conditions were specifically excluded based on a normal orthopaedic examination and no evidence of an overt orthopaedic condition on pelvic limb radiography or computed tomography when available for review.

Owners of dogs that potentially met the inclusion criteria were informed of the clinical trial at time of admission, and offered an initial ESI at time of diagnosis. Decompressive surgery was offered to the veterinary patients when ESI was unsuccessful or following relapse of clinical signs. Procedures and time frames are detailed below.

Owner questionnaires were devised enquiring about the presence of typical clinical features of DLSS. Inferred pain, mobility and quality of life were assessed through three numerical 0 to 10 whole number scales: when referring to inferred pain, 0 corresponded to no pain and 10 to extreme pain; when referring to mobility and quality of life, 0 meant poor and 10 meant good mobility or quality of life. Three questionnaires were devised and provided to the owners at three different time-points: at initial

consultation (Supplement 1), two to four weeks following ESI (Supplement 2), and six to eight weeks following surgical management (Supplement 3).

Signalment, weight, duration of clinical signs, previous treatments attempted, clinical and neurological findings were recorded. Dogs were initially classified into clinical severity groups through the use of a mild, moderate and severe grading scoring system (Gomes et al., 2018). Mild cases presented DLSS compatible clinical signs (e.g. lumbosacral pain, reluctance to climb stairs/jump/raise up, lameness, muscle atrophy) but no neurological deficits. Moderate cases presented DLSS compatible clinical signs plus neurological deficits considered moderate (reduced flexor withdrawal, proprioceptive deficits, nerve root signature/toe touching). Severe cases presented DLSS compatible clinical signs plus neurological deficits considered more severe (tail paresis, absent perineal reflex). Dogs were classified as pet dogs or working dogs, the latter category including agility dogs. Daily exercise length was classified as above or below an hour.

Diagnosis and epidural steroid injection

Following clinical and MRI diagnosis of DLSS, each dog underwent an ESI under general anaesthesia. General anaesthesia protocol was standardised for all dogs. Instillation of methylprednisolone acetate (Depo-Medrone 40 mg/ml, Pfizer) was performed into the lumbosacral epidural space in accordance with a previously reported dosage protocol, of 1 mg/kg with a minimal volume of 0.5 ml (Janssens et al., 2009). In order to confirm the correct placement of the needle, a neurostimulation technique was performed following a previously validated method, with the animal in sternal decubitus (Garcia-Pereira et al., 2010). A disposable spinal needle electrode (Natus TECA MyoJect, 50 mm length, 25 gauge) was placed and muscle twitching of the tail at a

stimulus intensity up to 0.30 mA was required before local instillation (Garcia-Pereira et al., 2010). Epidural steroid injections were performed by the authors. Following ESI, all dogs were discharged with instructions for restricted exercise and continuation of their current oral treatment protocol in order to avoid interference with ESI, except when managed with non-steroidal anti-inflammatory drugs which were stopped. Restricted exercise instructions were that owners should only take the dogs on short-walks on a lead, and that strenuous activity (e.g. agility) should be avoided until a response to treatment was identifiable.

The owners were handed the first questionnaire at initial consultation (Supplement 1). A follow-up consultation was performed between two to four weeks later, in accordance with previously reported median length of ESI effect of 11 days (range, 4–14 days) (Janssens et al., 2009). A second questionnaire was handed to the owners at that time (Supplement 2). Information was obtained from owners regarding complications, particularly focusing on signs of systemic absorption of corticosteroids such as polyphagia, polydipsia and polydipsia (Behrend and Kemppainen, 1997; Salmelin et al., 2019). The length of time until clinical response was observed through an open question in the second questionnaire.

Surgical decompression

Surgical decompression was offered to veterinary patients following a minimum period of two weeks following ESI, when unsuccessful or after relapse of clinical signs. Lateral foraminotomy (unilateral or bilateral) was performed when there was evidence of foraminal stenosis at the level of the lumbosacral junction, with a concurrent dorsal laminectomy when there was evidence of midline vertebral canal stenosis (Gödde and Steffen, 2007; Gomes et al., 2018). Concurrent L7-S1 discectomy was not performed

(Gomes et al., 2018). Surgical procedures were performed by two board-certified neurologists. Following surgery, dogs were discharged with instructions of cage rest for four to six weeks, rehabilitation under guidance of a qualified animal physiotherapist and concurrent pain-relief as required (e.g. non-steroidal anti-inflammatory medication and/or gabapentin). Dogs would then be allowed to gradually resume regular exercise and routine. Follow-up consultations were performed between six to eight weeks following surgery and a third questionnaire was given to the owners (Supplement 2).

Outcome

Outcome was divided into (1) clinical outcome, as assessed by a board certified neurologist on follow-up consultations, (2) owner inferred outcome based on pain, mobility and quality of life scores obtained through questionnaires.

Clinical outcome to both ESI and surgical decompression was considered (1) complete if clinical signs had resolved at follow-up consultations (2) partial if there was substantial but incomplete improvement in clinical signs (3) failed if the dog did not improve or deteriorated further. Relapse was assessed following initial response to ESI or surgical decompression, being defined as deterioration of clinical signs following an initial improvement. Time from ESI to relapse was obtained at the time of completion of the second questionnaire or, if occurring later, through telephone interviews with the owners. Follow-up time was collected for dogs without relapse through telephone interviews with the owners at the time of completion of this study.

In dogs undergoing both ESI and surgical decompression, comparison of clinical and owner inferred outcome was performed.

Results

A total of 88 dogs were consecutively assessed for enrolment for a suspected diagnosis of DLSS. Thirty-eight dogs were excluded for presenting a non-DLSS diagnosis, details are described in Fig. 1. Of the remaining 50 dogs, 41 dogs underwent ESI with nine dogs receiving an alternative treatment modality at the owner's request. Following ESI, nine dogs did not return for a follow-up consult failing to complete the second questionnaire. Thirty-two dogs were re-examined and completed the questionnaire following ESI. All dogs had undergone unsuccessful medical management through non-standardised medication protocols and restricted exercise before presentation.

Animals

Breed distribution was Labrador Retriever (*n* = 6), Border Collie (4), Crossbreed (4), German Shepherd Dog (3), Golden Retriever (2), Airedale Terrier, Beagle, Belgian Shepherd Dog, Boxer, Chinese Shar-pei, Cocker Spaniel, Dalmatian, German Pointer, Rhodesian Ridgeback, Rottweiler, Siberian Husky, Springer Spaniel, Staffordshire Bull Terrier (1 for each). Seventeen males and 15 females were identified with a mean age of 75.1 months (median, 70.5; range, 15-150). Mean duration of clinical signs before diagnosis was of 4.7 months (median, 4; range, 0.25-12) and mean weight was of 27.4 kg (median, 27.1; range, 6.8-42.6). A total of five dogs were working or agility dogs (15.6%), with 17 (53.1%) being exercised for over 1 hour daily.

Outcome

Clinical outcome is detailed in Table 1. Thirty-two dogs were assessed following ESI. Initial grading score was mild in 14 (43.8%), moderate in 15 (46.9%) and severe in three (9.4%) dogs.

An improvement after ESI was seen in 27/32 dogs (84.4%) with partial response in 14 dogs and a complete response in 13 dogs. In five dogs (15.6%) no clinical response to ESI was evident. All five dogs where no clinical response was identifiable had subsequent surgical decompression. Of the 14 dogs in which a partial response was seen, nine relapsed with seven having surgical decompression, one opting to have ESI repeated and one being refused further treatment by their owners; the remaining five were lost to long term follow-up. Of the 13 dogs with a complete response to ESI, eight relapsed with five subsequently having surgical decompression and three being refused further treatment by their owners; the remaining five had persistent improvement without relapse. Information on relapse post-ESI was available in 22 dogs and occurred in 17 (77.2%), at a mean of 2.4 months (median, 2; range, 0.5-6). The five dogs with a persistent improvement without relapse following ESI had a last-contact mean follow-up time of 9.4 months (median, 8; range, 2-21).

Time length until clinical response following ESI was only detailed by the owners of 17 dogs and was a mean of 12.9 days (median, 14; range, 2-28). No complications were identified from ESI and a single dog presented transient clinical signs compatible with systemic absorption of corticosteroids.

A total of 17 dogs underwent decompressive surgery (Fig. 1). Initial grading score was mild in six, and moderate in 11 dogs. Bilateral lateral foraminotomy was performed as a standalone procedure in four dogs and with concurrent dorsal laminectomy in 13 dogs. Post-surgical improvement was identified in all 17 dogs, with a complete response seen in eight dogs and a partial response in nine dogs. No intraoperative complications were identified. In the five dogs where ESI failed to show improvement, all five improved post-surgically with partial response in two dogs and a complete response in three dogs (Table 1).

The results of owner inferred outcome are described in table 2 and depicted in Fig. 2 and Fig. 3 In the whole population receiving an ESI, there was a trend towards reduced pain, increased mobility, and greater quality of life score (Fig. 2). This same trend was identified following surgical decompression, particularly in term of pain scores (Fig. 3). An extreme post-surgical outlier of the quality of life marker (0 mark) was that of a five-year-old beagle which underwent bilateral foraminotomy combined with dorsal laminectomy (dog 15). This beagle achieved increased mobility and reduced pain, however, was assessed by the owner as having a significant reduction in quality of life due to the development of urinary and faecal incontinence following surgery.

Discussion

This is the first study that prospectively assesses treatment of a dog population clinically affected by DLSS (Jeffery el al., 2014). This study evaluated the value of a single instillation ESI as treatment in DLSS, comparing outcome between both ESI and surgical decompression as well as its potential value as a predictor of surgical outcome.

The results of this clinical trial were in accordance with previous studies, confirming the safety and efficacy of ESI (Janssens el al., 2009; Liotta et al., 2016; Salmelin et al., 2019). Contrary to the results reported by Janssens and others (Janssens et al., 2009), 15.6% failed to demonstrate a clinical response in our study. We measured both the duration of the clinical effect of ESI (termed here as relapse), and the length of time it took for ESI to be effective according to owners. A clinical response to ESI took a mean of 12.9 days, with some dogs taking up to 28 days for a response to be noticeable. Relapse occurred within six months of ESI with a median of two months, longer than the previously reported median of 11 days (Janssens et al., 2009). This is compatible with reports in people suffering from low-back pain, where as many as 50%

of patients will be pain-free for two weeks, with only a very limited number of cases being pain-free after six months (White et al., 1980, Parr et al., 2009). Both values reveal a variable response of individuals to ESI, with ESI sometimes taking longer to act or having a longer effect than previously reported in dogs (Janssens et al., 2009).

Interestingly, a subset of our population (15.6%) had a sustained, complete response to a single ESI, without relapse, with a mean follow-up time of 9.4 months. This demonstrates that a subset of DLSS affected dogs can respond to a single-instillation of ESI for a longer period of time than previously reported. Further prospective studies with more dogs and a longer follow-up time would be required in order to confirm if clinical signs do eventually relapse and to help identify factors associated with such a protracted response.

In humans, despite the frequent utilisation of ESI for treatment of lumbar radiculopathy, its efficacy and indications are still matter of debate (Parr et al., 2009; Roberts et al., 2009; Cohen et al., 2013). Instillation of steroids, when utilised as a single treatment, has been shown to be equivalent to a single instillation of bupivacaine or saline (Roberts et al., 2009). In dogs, only the effect of methylprednisolone delivered into the epidural space in dogs with DLSS has been assessed originally (Janssens et al., 2009) and in this clinical trial. In humans despite reports of usage of methylprednisolone, hydrocortisone and triamcinolone, results are conflicting in terms of relative benefit (McLain et al., 2005). Evaluation of a placebo or lidocaine administered into the epidural space would be of great interest in dogs with DLSS given the findings in people.

The mechanism of action of ESI is still not well understood and it is most likely multifactorial. Corticosteroids are commonly utilised in neurological conditions in dogs, mainly due to its anti-inflammatory or immunosuppressive effects (Platt et al., 2005).

Corticosteroids can directly or indirectly inhibit the synthesis or release of pro-inflammatory mediators, alter neuromuscular junction and neuronal conductivity (namely nociceptive C-fibre conduction), and reduce oedema formation secondary to increased capillary damage and permeability (McLain et al., 2005). It is also possible that corticosteroids act in other unknown distinct mechanisms, considering its potential and sometimes deleterious effects on neural development and regeneration (Chari, 2014). The direct instillation of an aqueous substance into the epidural space could lead to osmotic dilution and removal of inflammatory mediators (Wilkinson and Cohen, 2013). There is also the advantage over oral medication of a more targeted corticosteroid delivery with a reduction of systemic effects (McLain et al., 2005). Epidural steroid injection is considered a relatively safe procedure in both dogs and humans (Janssens et al., 2009; Parr et al., 2009; Karaman 2011; Liotta et al., 2016; Salmelin et al., 2019), although severe complications secondary to an epidural injection have been reported in a dog (Remedios et al., 1996). ESI is a less-invasive and more affordable procedure than surgery. However, the need for repeated instillations can lead to cumulative costs and reduce owner compliance (Janssens et al., 2009). It also must be noted, that despite the delivery of a potent anti-inflammatory drug such as methylprednisolone over the affected region, inflammation appears to be a rare finding in cases of foraminal stenosis and secondary nerve root enlargement (Matiasek et al., 2008).

Comparison of clinical outcome in the 17 dogs undergoing both ESI and subsequent surgical decompression, revealed that a complete response was obtained in 53% of cases (9/17) following surgery, against only 17.6% (3/17) following initial ESI (Table 1). Clinical improvement was attained following surgery in all cases, despite 29.4% (5/17) having previously failed to respond to ESI alone. In terms of owner

perceived outcome, ESI was subjectively not as effective as surgical decompression in regard to improving owner assessed mobility, quality of life but particularly pain (Fig. 3). There was a trend towards reduced pain, increased mobility, and greater quality of life score between sequential modalities, which appeared subjectively more marked in the pain score, where a difference of over three score points was observed between both mean and median initial and post-surgical score points. This data seems to indicate that decompressive surgery might be a superior treatment to single ESI in DLSS cases.

The role of ESI as an accurate predictor of clinical or owner perceived outcome following decompressive surgery is less clear. All dogs enrolled in and completing this study, which underwent surgical decompression, showed a positive response. This was the case despite some having previously failed to respond to a single-instillation ESI. Also, some dogs responded so well to a single ESI that subsequent surgical decompression was not performed. Therefore, our initial hypothesis that a positive ESI response could indicate a successful outcome of subsequent decompression, could not be confirmed.

Needle placement confirmation for epidural injection relies on techniques such as the hanging-drop, loss-of-resistance test, pressure-waves measurement, epidurography, fluoroscopy, ultrasonography and epidural electrical stimulation (Valverde, 2008; Adami and Gendron, 2017). The epidural electrical stimulation method utilised in this study has been reported to possess a specificity of 93% and a sensitivity of 74% in the lumbosacral joint (Garcia-Pereira et al., 2010). Despite all epidural injections being performed by experienced clinicians, it is possible that the dogs that failed to respond to ESI may have been injected outside of the epidural space. However, no systemic side-effects (e.g. polyuria or polydipsia) were reported by the owners of those dogs.

All dogs presenting with concurrent pathologies including pelvic limb orthopaedic disease were excluded from this study. Despite not being within the scope of this study, the 84.4% short term response rate to ESI suggests that ESI may be a useful diagnostic procedure to help establish the contribution of DLSS to pelvic limb dysfunction from concurrent pathologies in dogs (e.g. acute or chronic orthopaedic disease affecting the hips or stifles).

A series of limitations exist in this study. Clinical outcome information relied on the expertise of the same people that performed the procedures, potentiating clinician bias. Owner perceived outcome is inherently subjective, prone to caregiver placebo effect that may be impacted by the relative cost of ESI versus surgical decompression. The utilisation of a subjective numeric grading for owner perceived outcome was not based on a previously validated method.

Conclusion

This study confirms the previously reported efficacy of ESI as a treatment of DLSS although a positive response was not achieved in all cases. The mechanisms behind this response remain unexplained. Epidural steroid injection appears inferior to surgical decompression according to clinical and owner perceived outcome. Although surgical decompression appears the preferable option to control long-term clinical signs relating to DLSS, ESI resulted in a complete and apparently long-term sustained resolution of clinical signs in a subset of dogs. This suggests that ESI may play a role in the management of DLSS cases when surgery is not an option, or indeed as an initial treatment at time of diagnosis. Response to ESI was not able to predict the short-term surgical outcome in this subset of dogs. Further studies are needed to develop a protocol to identify veterinary patients which might respond long term to ESI alone.

Conflict of interest statement

None of the authors has any other financial or personal relationships that could inappropriately influence or bias the content of the paper.

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Appendix A: Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi: …

References

Adami, C. and Gendron, K., 2017. What is the evidence? The issue of verifying correct needle position during epidural anaesthesia in dogs. Veterinary Anaesthesia and Analgesia 44(2), 212-218.

Behrend, E.N., Kemppainen, R.J., 1997. Glucocorticoid therapy: pharmacology, indications, and complications. Veterinary Clinics of North America Small Animal Practice 27(2), 187-213.

Buttermann, G.R., 2004. Treatment of lumbar disc herniation: epidural steroid injection compared with discectomy: a prospective, randomized study. The Journal of Bone and Joint Surgery 86(4), 670-679.

Chari, D.M., 2014. How do corticosteroids influence myelin genesis in the central nervous system?. Neural Regeneration Research 9(9), 909.

Cohen, S. P., Bicket, M. C., Jamison, D., Wilkinson, I., & Rathmell, J. P., 2013. Epidural steroids: a comprehensive, evidence-based review. Regional Anesthesia and Pain Medicine 38, 175-200.

Danielsson, F., Sjöström, L., 1999. Surgical treatment of degenerative lumbosacral stenosis in dogs. Veterinary Surgery 28(2), 91-98.

De Decker, S., Wawrzenski, L.A., Volk, H.A., 2014. Clinical signs and outcome of dogs treated medically for degenerative lumbosacral stenosis: 98 cases (2004–2012). Journal of the American Veterinary Medical Association 245(4), 408-413.

De Risio, L., Sharp, N.J., Olby, N.J., Muñana, K.R., Thomas, W.B., 2001. Predictors of outcome after dorsal decompressive laminectomy for degenerative lumbosacral

429 stenosis in dogs: 69 cases (1987–1997). Journal of the American Veterinary
430 Medical Association 219(5), 624-628.
431 Denny, H.R., Gibbs, C., Holt, P.E., 1982. The diagnosis and treatment of cauda equina
432 lesions in the dog. Journal of Small Animal Practice, 23(8), 425-443.
433 Garcia-Pereira, F.L., Hauptman, J., Shih, A.C., Laird, S.E. and Pease, A., 2010.
434 Evaluation of electric neurostimulation to confirm correct placement of
435 lumbosacral epidural injections in dogs. American Journal of Veterinary
436 Research 71(2), 157-160.
437 Gödde, T., Steffen, F., 2007. Surgical treatment of lumbosacral foraminal stenosis using
438 a lateral approach in twenty dogs with degenerative lumbosacral
439 stenosis. Veterinary Surgery 36(7), 705-713.
440 Golini, L., Kircher, P.R., Lewis, F.I., Steffen, F., 2014. Transarticular fixation with
441 cortical screws combined with dorsal laminectomy and partial discectomy as
442 surgical treatment of degenerative lumbosacral stenosis in 17 dogs: clinical and
443 computed tomography follow-up. Veterinary Surgery 43(4), 405-413.
444 Gomes, S.A., Lowrie, M., Targett, M., 2018. Long-term outcome following lateral
445 foraminotomy as treatment for canine degenerative lumbosacral
446 stenosis. Veterinary Record 183(11), 352–356.
447 Hankin, E.J., Jerram, R.M., Walker, A.M., King, M.D., Warman, C.G., 2012.
448 Transarticular facet screw stabilization and dorsal laminectomy in 26 dogs with
449 degenerative lumbosacral stenosis with instability. Veterinary Surgery 41(5),
450 611-619.
451 Janssens, L., Beosier, Y., Daems, R., 2009. Lumbosacral degenerative stenosis in the
452 dog. The results of epidural infiltration with methylprednisolone acetate: a
453 retrospective study. Veterinary and Comparative Orthopaedics and
454 Traumatology 22(06), 486-491.
455 Janssens, L.A.A., Moens, Y., Coppens, P., Peremans, K., Vinck, H., 2000. Lumbosacral
456 degenerative stenosis in the dog - the results of dorsal decompression with
457 dorsal anulectomy and nucleotomy. Veterinary and Comparative Orthopaedics
458 and Traumatology 13(02), 97-103.
459 Jeffery, N.D., Barker, A., Harcourt-Brown, T., 2014. What progress has been made in
460 the understanding and treatment of degenerative lumbosacral stenosis in dogs
461 during the past 30 years?. The Veterinary Journal 201(1), 9-14.
462 Jones, J.C., Banfield, C.M., Ward, D.L., 2000. Association between postoperative
463 outcome and results of magnetic resonance imaging and computed tomography
464 in working dogs with degenerative lumbosacral stenosis. Journal of the
465 American Veterinary Medical Association 216(11), 1769-1774.
466 Karaman, H., Kavak, G.Ö., Tüfek, A., Yldrm, Z.B., 2011. The complications of
467 transforaminal lumbar epidural steroid injections. Spine 36(13), 819-824.
468 Linn, L.L., Bartels, K.E., Rochat, M.C., Payton, M.E., Moore, G.E., 2003. Lumbosacral
469 stenosis in 29 military working dogs: epidemiologic findings and outcome after
470 surgical intervention (1990–1999). Veterinary Surgery 32(1), 21-29.
471 Liotta, A. P., Girod, M., Peeters, D., Sandersen, C., Couvreur, T., Bolen, G., 2016.
472 Clinical effects of computed tomography–guided lumbosacral facet joint,
473 transforaminal epidural, and translaminar epidural injections of
474 methylprednisolone acetate in healthy dogs. American Journal of Veterinary
475 Research 77(10), 1132-1139.
476 Matiasek, K., Steffen, F., Schmahl, W., Gödde, T., 2008. Back to the roots - radicular
477 pathology in foraminal stenosis (5 cases). Journal of Veterinary Internal
478 Medicine 22 (29), 504.

McLain, R.F., Kapural, L. and Mekhail, N.A., 2005. Epidural steroid therapy for back and leg pain: mechanisms of action and efficacy. The Spine Journal 5(2), 191-201.

Ness, M.G., 1994. Degenerative lumbosacral stenosis in the dog: a review of 30 cases. Journal of Small Animal Practice 35(4), 185-190.

Parr, A.T., Diwan, S., Abdi, S., 2009. Lumbar interlaminar epidural injections in managing chronic low back and lower extremity pain: a systematic review. Pain Physician 12(1), 163–188.

Platt, S.R., Abramson, C.J. and Garosi, L.S., 2005. Administering corticosteroids in neurologic diseases. Compendium on Continuing Education for the Practicing Veterinarian 27, 210-220.

Remedios, A.M., Wagner, R., Caulkett, N.A., Duke, T., 1996. Epidural abscess and discospondylitis in a dog after administration of a lumbosacral epidural analgesic. The Canadian Veterinary Journal 37(2), 106.

Roberts, S.T., Willick, S.E., Rho, M.E., Rittenberg, J.D., 2009. Efficacy of lumbosacral transforaminal epidural steroid injections: a systematic review. PM & R : the journal of injury, function, and rehabilitation 1(7), 657-668.

Salmelin, B., Fitzpatrick, N., Rose J., Driver C., 2019. Safety profile of methylprednisolone acetate epidural injection in dogs treated for lumbosacral disease. In BSAVA Congress Proceedings, Apr 1, BSAVA Library, 546-546.

Smolders, L.A., Voorhout, G., van de Ven, R., Bergknut, N., Grinwis, G.C., Hazewinkel, H.A. and Meij, B.P., 2012. Pedicle screw-rod fixation of the canine lumbosacral junction. Veterinary Surgery 41(6), 720-732.

Suwankong, N., Meij, B.P., Voorhout, G., De Boer, A.H., Hazewinkel, H.A.W., 2008. Review and retrospective analysis of degenerative lumbosacral stenosis in 156 dogs treated by dorsal laminectomy. Veterinary and Comparative Orthopaedics and Traumatology 21(03), 285-293.

Valverde, A., 2008. Epidural analgesia and anesthesia in dogs and cats. Veterinary Clinics of North America: Small Animal Practice 38(6),1205-1230.

White, A.H., Derby, R., Wynne, G., 1980. Epidural injections for the diagnosis and treatment of low-back pain. Spine 5(1), 78-86.

Wilkinson, I., Cohen, S. P., 2013. Epidural steroids for spinal pain and radiculopathy: a narrative, evidence-based review. Current Opinion in Anesthesiology 26(5), 562-572.

514 **Tables**

515 **Table 1.**

516 Detailed clinical outcome.

517

	Initial grading		Clinical response to epidural steroid injection	Relapse			Surgery performed	Clinical response to decompression
	Severity	Numerical		Yes/No	Time to relapse (months)	Follow-up time (months)		
Case 1	Moderate	12	Partial	Yes	3	NA	BF+DL	Partial
Case 2	Mild	13	Partial	Yes	0.5	NA	BF+DL	Complete
Case 3	Mild	17	Complete	Yes	3	NA	No: owner refused	NA
Case 4	Mild	17	Partial	Yes	1	NA	BF+DL	Partial
Case 5	Moderate	10	Partial	Yes	3	NA	BF	Complete
Case 6	Moderate	10	Complete	Yes	3	NA	No: owner refused	NA
Case 7	Mild	18	Complete	Yes	3	NA	BF+DL	Complete
Case 8	Mild	15	Complete	No	NA	21	No: persistent improvement	NA
Case 9	Moderate	11	Failed	Yes	0.75	NA	BF+DL	Partial
Case 10	Mild	17	Partial	Yes	6	NA	No: repeat ESI	NA
Case 11	Moderate	13	Failed	Yes	2	NA	BF+DL	Complete
Case 12	Mild	16	Partial	Yes	2	NA	BF+DL	Complete
Case 13	Moderate	13	Complete	Yes	0.75	NA	BF+DL	Partial
Case 14	Moderate	11	Complete	Yes	2	NA	BF+DL	Complete
Case 15	Mild	15	Failed	Yes	0.75	NA	BF+DL	Complete
Case 16	Moderate	12	Partial	Yes	0.5	NA	No: owner refused	NA
Case 17	Mild	15	Complete	No	NA	13	No: persistent improvement	NA
Case 18	Moderate	15	Failed	Yes	2	NA	BF+DL	Complete
Case 19	Moderate	15	Partial	Yes	2	NA	BF+DL	Complete
Case 20	Moderate	14	Partial	Yes	0.75	NA	BF	Partial
Case 21	Moderate	14	Partial	Yes	5	NA	BF	Partial
Case 22	Mild	16	Partial	Lost	NA	NA	Lost	NA
Case 23	Severe	7	Partial	Lost	NA	NA	Lost	NA
Case 24	Severe	12	Complete	Yes	2	NA	No: owner refused	NA
Case 25	Moderate	15	Partial	Yes	2	NA	BF	Partial
Case 26	Severe	13	Complete	No	NA	3	No: persistent improvement	NA
Case 27	Mild	16	Failed	Yes	0.5	NA	BF+DL	Partial
Case 28	Moderate	15	Complete	No	NA	2	No: persistent improvement	NA
Case 29	Mild	14	Complete	No	NA	8	No: persistent improvement	NA
Case 30	Mild	17	Partial	Lost	NA	NA	Lost	NA

Case 31	Moderate	12	Partial	Lost	NA	NA	Lost	NA
Case 32	Mild	17	Partial	Lost	NA	NA	Lost	NA

518 BF, Bilateral foraminotomy; DL, Dorsal laminectomy; ESI, Epidural steroid injection;
519 Lost, Lost to follow-up after recheck following epidural steroid injection; NA, Non
520 applicable.

521

522 **Table 2**

523 Detailed owner perceived outcome for dogs having both ESI and decompressive

524 surgery.

	General population (*n* = 32)		Surgically managed (*n* = 17)		
	Initial grade mean (median, minimum-maximum)	Post-epidural mean (median, minimum-maximum)	Initial grade mean (median, minimum-maximum)	Post-epidural mean (median, minimum-maximum)	Post-surgical mean (median, minimum-maximum)
Pain (0 no pain – 10 extreme pain)	5.4 (5; 2-10)	2.9 (3; 0-6)	5 (5; 2-8)	3.4 (4; 0-6)	1.3 (0; 0-5)
Mobility (0 poor – 10 good)	6.2 (6; 2-10)	7.8 (8; 3-10)	6.5 (7; 3-10)	7.5 (8; 5-10)	9.1 (9; 7-10)
Quality of life (0 poor – 10 good)	6.2 (6; 0-10)	7.8 (8.5; 2-10)	6.5 (6; 3-9)	7.2 (8; 2-10)	8.6 (9; 0-10)

525

526

Figure legends

Fig. 1. Diagram depicting the clinical trial sequence, included dogs and reasons for exclusion.

Fig. 2. Box and whiskers plots representing owner perceived pain, mobility and quality of life scores of the whole population (n = 32) at two time points, initial and following epidural steroid injection (ESI). Circles beyond the whiskers indicate outliers, with asterisks identifying extreme outliers.

Fig. 3. Box and whiskers plots representing owner perceived pain, mobility and quality of life scores of the dogs receiving surgery (n = 17) at three time points, initial, following epidural steroid injection (ESI), and following surgery decompression. Circles beyond the whiskers indicate outliers, with asterisks identifying extreme outliers.